

Different Approaches For Ensuring Performance/Reliability of Plastic Encapsulated Microcircuits (PEMs) in Space Applications

R. David Gerke
Mike Sandor
Shri Agarwal

NASA/Jet Propulsion Lab
Pasadena, CA

Andrew F. Moor
Kim A. Cooper

JHU/Applied Physics Lab
Laurel, MD

- JPL's & APL's Experiences with PEMs

- ▲ Mitigating Risk

- ◆ Tailored Testing Approach
- ◆ Derating Practices

- ▲ Program Results

- ◆ JPL: MARS01 Pancam
- ◆ APL: APEX & TIMED
- ◆ Significant Findings

- ▲ Summary

- Space Environment Not Intended Application for PEMs
 - ▲ Screening and/or Qualification Testing Needed to Compliment Manufacturer's Approach
 - ◆ Must Meet Specific Mission Requirements
 - ▲ Continued Use of Derating Practices
- Screening Process
 - ▲ Verification at The Mission Temperature Profile
 - ◆ Electrical Measurements, Radiographic Inspection, Visual & Mechanical Inspection
 - ▲ JPL: Burn-in & C-SAM

- Qualification Process

- ▲ Destructive Physical Analysis, & Radiation (if Required)
- ▲ JPL: Mini Part Qual to Simulate Mission Life
- ▲ APL: Life Test, Temperature Cycling & Steady-State Temperature Humidity Bias
 - ◆ Temperature Cycling & Steady-State Temperature Humidity Bias Only Performed If Data Can Not Be Obtained From Manufacturer

- JPL - MARS01 Pancam

- ▲ Mission Life < 1 Year

- ◆ 1500 Hours Operating

- ▲ Operating Temperature (Day Only)

- ◆ -50° C to + 10° C

- ▲ Number of Temperature Cycles

- ◆ Approximately 365

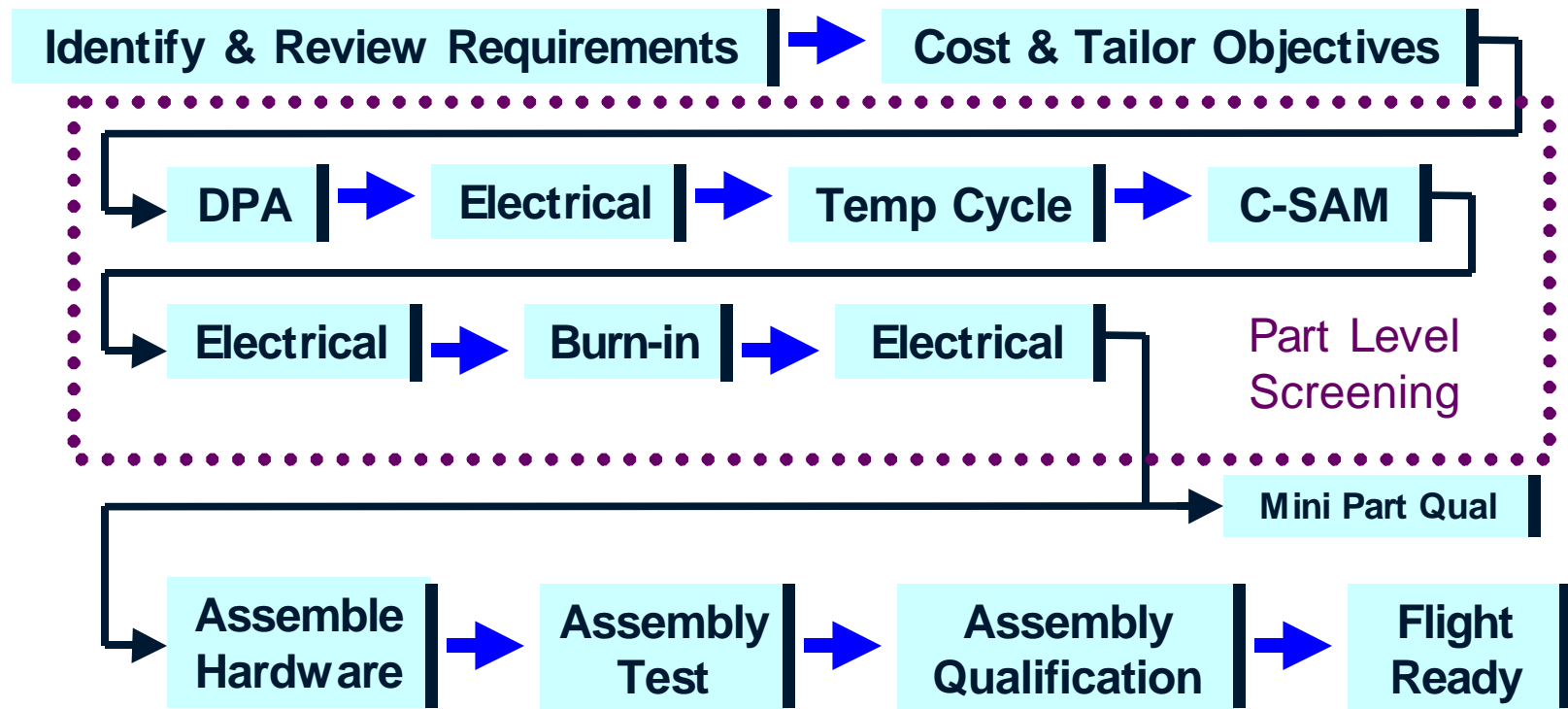
- ▲ Outgassing on Optics a Concern

- ◆ Proximity of PEMs to Optics

- ▲ Environmental Moisture Not a Concern

- ◆ Followed recommended Industry guidelines for PEMs

● JPL - MARS01 Pancam Test Flow:



- ◆ **3 Vendors / 3 Part Types:** Amplifier, Analog-Digital Converter (A-D), & DC-DC Converter (DC-DC)

- JPL - MARS01 Pancam Test Results:

Test	Amplifier	A-D	DC-DC
External Visual	0/4	0/8	0/4
Radiographic	0/4	0/8	0/4
Internal Visual	0/4	0/8	0/4
SEM	0/4	1/8	0/4
C-SAM (Top)	0/78	30/78	0/78
C-SAM (Bottom)	3/78	8/78	16/78

- ◆ **SEM:** Voids in The Side-wall Metallization at Contact Windows
- ◆ **C-SAM:** Reject Criteria Defined by JPL

● JPL - MARS01 Pancam Test Results:

Test	Amplifier	A-D	DC-DC
Electrical @+25°C (Pre Burn-in)	0/78	10/78	2/78
Electrical @+55°C (Pre Burn-in)	0/78	0/68	1/76
Electrical @+25°C (Post Burn-in)	0/78	0/68	0/75
Electrical @-55°C (Post Burn-in)	0/78	3/68	0/75
Electrical @+25°C (Post Qual)	0/10	0/10	0/10
Electrical @-55°C (Post Qual)	0/10	0/10	0/10

- ◆ Parametric Failures: 13 (Pre Burn-In)
- ◆ Functional Failures: 3 (Post Burn-In)

- APL - APEX Program

- ▲ Mission Life < 1 Year

- ◆ 17 Minutes Operating

- ▲ Operating Temperature

- ◆ 0° C to + 25° C

- ▲ Sub-Orbital Mission

- ◆ Black Brandt XII Sounding Rocket

- ▲ Outgassing & Radiation Not Concern

- ◆ Due to Short Duration of Mission

- ▲ Environmental Moisture Not a Concern

- ◆ No Special Handling Precautions Taken

- APL - APEX Program Test Flow:
 - ▲ Environmental Stress Screening at Board Level in Lieu of Piece-part Screening
 - ◆ 10 Powered Temperature Cycles, -10° C to + 60° C
 - ▲ Vibration at Box, Module, & Stack Level
 - ◆ Sinusoidal & Random
 - ▲ RF Interference & Magnetic Calibration Test at Stack Level
 - ◆ “Plugs-Out” Test

- APL - APEX Program Test Results:
 - ▲ No Failures During Integration & Test
 - ▲ Successfully Launched on January 22, 1999
 - ▲ Preliminary Data Analysis: All Science Goals Met or Exceeded
 - ▲ Detailed Data Analysis Ongoing
 - ▲ Planning for Next Mission Underway

- APL - TIMED Program

- ▲ Mission Life > 1 Year

- ◆ 2 Years Operating

- ▲ Ground-Based Test Temperature

- ◆ -40° C to + 100° C

- ▲ On-Orbit Operating Temperature

- ◆ 0° C to + 50° C

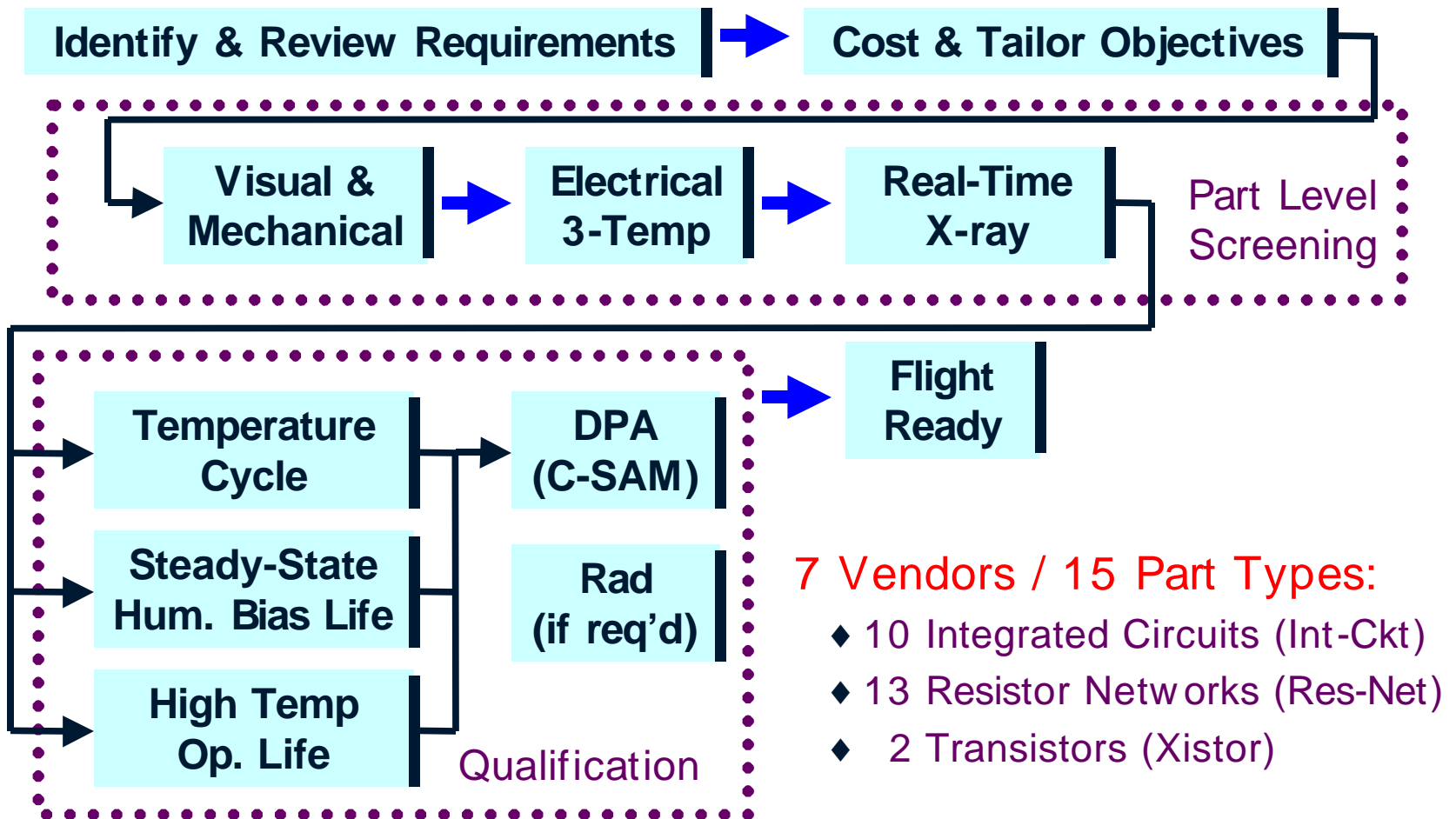
- ▲ Outgassing & Radiation a Concern

- ◆ All Parts Assessed and/or Tested

- ▲ Environmental Moisture a Concern

- ◆ Use of Dry-Box, Bake-Out, & Conformal Coat

● APL - TIMED Program Test Flow :



- APL - TIMED Program Screening Results:

Test	Int-Ckt	Res-Net	Xistor
External Visual	7/754	3/2375	3/378
Radiographic	5/593	18/977	0/157
Electrical @-40°C	0/828	87/1520	0/157
Electrical @+25°C	4/828	36/1520	0/157
Electrical @+100°C	0/828	36/1520	0/157

● APL - TIMED Program Screening Results:

▲ Int-Ckt:

- ◆ 4 Electrical Failures Attributable to Single Line Item
- ◆ All + 25° C Parametric (3 PSRR; 1 AOL)
- ◆ Lot Not Tested at Temperature (Fixture limitations)

▲ Res-Net:

- ◆ Electrical Failures Attributable to Single Line Item
- ◆ 36 Pieces Exceeded Resistance All 3 Temperatures
- ◆ Fixture Limitations Suspected For High Failure Rate
 - Additional Tolerance Can Lead to False Readings
- ◆ Only 2 of 18 Radiographic Failures Legitimate
 - 16 Rejected For Loss of Traceability

- APL - TIMED Program Qualification Results:

Test	Int-Ckt	Res-Net	Xistor
Temperature Cycling	2/60	0/32	N/A
Steady-State Hum. Bias Life	1/30	N/A	N/A
DPA (including C-SAM)	12/35	0/35	3/3
High-Temp Op. Life @-40°C	0/132	0/44	1/22
High-Temp Op. Life @+25°C	0/132	0/44	0/22
High-Temp Op. Life @+100°C	3/132	2/44	1/22

● APL - TIMED Program Qualification Results:

▲ Temperature Cycling:

- ◆ Failures Attributable to Single Line Item
- ◆ Parts Not Properly Soldered to Test Board
- ◆ Reworked Parts Passed
- ◆ Results of 1 Xistor Test Pending

▲ Steady-State Hum. Bias Life:

- ◆ Failure Attributable to Single Line Item
- ◆ Failed Functionally Post-200 Hour Measurements
- ◆ Passed Post-100 Hour Measurements
- ◆ 100 Hours Exceeds 2X Mission Life (N. Sinnadurai Eq.)
- ◆ Results of 1 Xistor Test Pending

● APL - TIMED Program Qualification Results:

▲ DPA:

- ◆ Failures Attributable to 15 Line Items
- ◆ All For Not Meeting MIL-STD-883 Step-Coverage Req.
 - 50% Minimum; 30% With Caveats
- ◆ Commercial Products Not Designed to 50% Criteria
- ◆ Mitigated by Program Life Testing

▲ C-SAM:

- ◆ 2 Int-Ckt Line Items Had Questionable C-SAM Results
 - Lead-Frame Element Delamination (top & back side)
 - Small Edge Delamination; These Were T/C Units
- ◆ Mitigated by Conformal Coating

● APL - TIMED Program Qualification Results:

▲ High-Temp Op. Life:

Int-Ckt:

- ◆ Failures Attributable to Single Line Item
- ◆ Exceeded + 100° C Limit For ICCL
- ◆ Devices at Threshold at Start of Test
- ◆ $\Delta < 10\%$

Res-Net:

- ◆ Failures Attributable to Single Line Item
- ◆ Exceeded Resistance at + 100° C
- ◆ Parts Rated to + 70° C
- ◆ $\Delta \approx 0.3\%$.

- APL - TIMED Program Qualification Results:

- ▲ High-Temp Op. Life (continued):

Xistor:

- ◆ Failures Attributable to Single Line Item
- ◆ 1 Device Exceeded - 40° C Limit For Hfe
- ◆ 1 Device Exceeded + 100° C Limit For ICBO
- ◆ Parts Rated to + 70° C
- ◆ Delta Not Available

- Significant Test Result Findings:

- ▲ DPA Accounted For Highest # of Failures

- ◆ Revision to MIL-STD-883, on Step-Coverage, to Accommodate Commercial Design Practices
- ◆ Alternate: Develop New Industry Standard

- ▲ Industry Standard on Acceptance / Rejection Criteria for C-SAM Needed

- ◆ Benefit of Performing Test is Considered Subjective By Some

- ▲ Low Fallout For Radiographic & External Visual

- ◆ Reassess Testing; Consider Sampling

- Commercial Parts Are “Mission Enabling”
 - ▲ Size, Weight, Speed, Cost = “Faster, Better, Cheaper”
- Use of PEMs Tailored Around Individual Mission Requirements
 - ▲ No “Universal” Approach
 - ▲ Not “Drop-in” Replacements to Military Parts
 - ▲ Testing to Enhance Manufacturer’s Data
 - ◆ Screening, Qualification, Environmental Stress Screening
 - ▲ Continued Use of Derating Practices
- JPL & APL Test Results Have Identified Two Key Areas That Need to be Addressed
 - ▲ Step-Coverage Criteria for DPA
 - ▲ Accept / Reject Criteria for C-SAM

- JPL Parts Home Page:
▲ parts.jpl.nasa.gov



- APL Home Page:
▲ www.jhuapl.edu

